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MORPHOLOGICAL EFFECTS ON PLANTS DUE TO DAMAGE BY GROWTH-REGULATOR WEED-KILLERS

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The great expansion in the use of synthetic plant growth regulators, principally for the control of weeds, has inevitably led to an increase in accidental damage to cultivated plants. This damage may occur as the result of an overdose to the crop being treated, or from drift on to susceptible crops of spray or dust particles, or of vapour where a volatile formulation has been used. Alternatively, the damage may be due to contamination of water supplies, soil, pots or implements used in the growing of the crop.

Many of the morphological effects of synthetic growth regulators at sub-lethal dosages are similar to, and can be confused with, the effects caused by pathogens, particularly those of certain viruses. The morphological effects are not so well known as they should be, and it is hoped that this article, describing them in general terms, may be of help to plant pathologists, as well as serving to introduce notes on specific examples of damage to individual cultivated plants which may be described or illustrated from time to time in this JOURNAL.

The chlorinated phenoxyacetic acids*, MCPA, 2, 4–D and 2, 4, 5–T, are the only growth-regulator herbicides used in the United Kingdom at the present time, and this paper refers chiefly to the visible effects caused by sub-lethal dosages of these compounds. Division may be made into (*a*) epinastic responses, occurring within a short period after exposure, and (*b*) formative effects, which are slower to appear, as they are usually dependent on meristematic growth and involve change in shape or pattern of organs.

Epinastic effects are due to unequal growth around the periphery of a stem, petiole or leaf sheath, giving rise to twisting of stems, shoots and petioles in any direction, and to the upward or downward movement of leaf blades. Under normal environmental conditions these effects become apparent within a few hours of exposure to the chemical. Within a day or so the epinasty may disappear and the plant resumes its normal appearance, but if the plant has received a higher dose or is more susceptible, the twisting of leaves and stems may persist.

Formative effects take time to develop before they become visible. For convenience they are considered below in relation to the particular organ affected. Deformities can only be described in general terms because their expression in individual plant species is dependent upon the normal morphology of the plant. Detailed histological studies of deformed organs and the way in which they arise have been limited to a few species, notably kidney beans and cotton, but it appears that, superficially at least, the same chain of events proceeds in a wide range of plants.

* MCPA = 2-methyl-4-chlorophenoxyacetic acid ; 2, 4–D = 2, 4-dichlorophenoxyacetic acid ; 2, 4, 5–T = 2, 4, 5-trichlorophenoxyacetic acid.

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DISTURBANCE OF SHOOT GROWTH

The balance of apical and axillary shoot growth may be upset, resulting in the reduction of apical dominance and an increase in axillary branching. This disturbance may occur in widely-divergent groups of plants from dicotyledons showing complete apical dominance, to grasses such as cereals, which, under the influence of the growth regulator, may show a continuation of tiller production beyond the normal limits. Cereals may also produce branches from nodes high up the main shoot, which often remain enclosed within the leaf sheath.

STEM DISTORTION

A very common effect is the excessive production of parenchyma in the stem. This may be localized and give rise to a tumour-like growth, or it may be general and result in the swelling of considerable lengths of the stem. Frequently associated with this increase in stem parenchyma is the development of large numbers of root initials. These initials may not develop sufficiently to reach the stem surface, and merely add to the swelling caused by the additional parenchyma. Alternatively, they may grow to such an extent and in such profusion that they rupture the cortex and epidermis and appear at the surface of the swollen stem as a dense mass of young root tissue. The associated splitting of the stem may lead to the invasion of secondary pathogens. In some plants the swelling and the development of root initials is confined to specific points on the stem, for example, the base and lower nodes of the cereal stem.

LEAF ABNORMALITIES

Formative effects on leaves frequently occur, and of all the deformities caused by synthetic growth regulators, these are the most likely to be confused with the effects of pathogens and other causal agents. In dicotyledons the most noticeable abnormalities in the leaf appear to arise through the failure of the interveinal areas to develop normally. Detailed histological studies have been made of affected leaves of kidney bean (Watson, 1948 ; Eames, 1951) and cotton (Gifford, 1953), and these do help to explain the morphological effects that occur. These workers show that the primary effect of the synthetic growth regulator is on meristematic cells which have reached a certain stage of development. The growth of the normal leaf is dependent on apical and lateral meristems. The apical initials appear to be unaffected or only slightly so, the leaf increasing in length in something like a normal manner. On the other hand, the activity of the lateral meristems responsible for the expansion in width of the leaf may be severely affected. The layers giving rise to upper and lower epidermis continue to function normally, but the intervening layers, which normally produce well-defined mesophyll and palisade layers, become disorganized. In the mesophyll, divisions occur in all planes, the cells produced resembling the parenchyma normally surrounding vascular bundles. These cells develop few or no chloroplasts and do not separate from one another to form intercellular spaces. Cells normally developing into palisade cells also turn into this same type of parenchyma. Accessory veins may also be formed.

The marginal initials themselves are not necessarily damaged and at a later stage may resume production of leaf blade tissue of normal type, which then forms a margin to the leaf. Cells which have developed beyond a certain stage at the time of treatment are unaffected, and for this reason certain portions of the lamina may be more affected than others ; for example, the base more than

the tip, and portions farthest from the principal veins more than those adjacent to veins.

The resultant effects of these histological changes on the morphology of the leaf are many and varied. The lack of interveinal development naturally influences leaf shape. In a slightly affected leaf or leaflet where the bulk of the lamina has already passed the susceptible stage, there may only be a narrowing at the base. This may be accompanied by a reduction in the depth of serration (Plate III, 2).

In a more severely affected instance the whole lamina may be very considerably narrowed and marginal serrations markedly increased in depth (Plate II, 2 and Plate III, 2). In extreme cases there appears to be virtually no interveinal development, the much narrowed leaf apparently consisting only of a tangled mass of vein tissues.

In compound leaves two or more leaflets may be fused together for part or all of their length. Fusion of whole leaves may likewise occur, giving a leaf with one fused mid-rib towards the base but forking distally to give two mid-ribs with their accompanying laminas (Plate III, 1). Partial fusion of the margins of two opposite leaves may occur on both sides around the apical meristem of the shoot, giving rise to a cup-shaped composite leaf forking into its two components at the top (Plate II, 1). In plants with more complicated phyllotaxy, such " cups " may be composed of more than two leaves. These cup-shaped formations enclose the terminal shoot and may impose a considerable constriction upon its development. If the enclosed shoot cannot grow freely upwards to the open top of the " cup," it may eventually rupture the side of the fused leaf formation and force its way out to continue growth. Some of the cup-shaped distortions are reminiscent of the naturally occurring " pitcher-leaves ", fairly common on brassicas, and described by Worsdell (1915).

The altered pattern of cell division gives rise to an abnormally thick leaf. It also causes considerable changes in surface appearance. Puckering and blistering frequently occurs, due to the uneven growth of the various cell layers within the lamina ; such distortion may be on a large scale, giving highly contorted leaves (Plate III, 1). The mid-rib and main veins may grow faster than the remainder of the leaf and therefore assume a serpentine appearance. An excess of parenchyma around the veins often gives increased ribbing over the veins on both dorsal and ventral surfaces. Because this parenchyma around the veins contains few chloroplasts, the veins assume an accentuated yellow appearance similar to the " vein-clearing " commonly occurring in the mosaic type of virus diseases. Where the leaf is composed largely of veins and this accompanying parenchyma, the leaf as a whole appears highly chlorotic. Around the leaf margins there may be a well-defined green band, due to the marginal meristem returning to the production of normal leaf tissue. Because this band of tissue grows more rapidly than that formed under the influence of the growth regulator but is still attached to the latter, it becomes ruffled. Another colour effect which may arise is a variegated pattern made up of the normal green of the interveinal tissue nearest the main veins and the chlorotic colour of the tissue distant from them. This variation is brought about when exposure to growth regulator comes too late to affect the earlier differentiated tissue adjacent to the veins.

Because the stage of development of the primordial cells is critical, only a few of the leaves on a shoot will be affected in instances of slight damage

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involving only one occasion of contact with the chemical. The basal leaves on the shoot are normal, followed by a zone of morphologically abnormal leaves, and a terminal zone in which normal leaves are again produced (Plate II, 2). At the time of exposure to a growth regulator, the primordia which are sensitive to damage may be enclosed within a bud which later becomes dormant. Thus, although the damage occurs at the time of exposure, it may not become visible until very much later, as in the example illustrated.

The majority of monocotyledonous leaves, because of their morphology, do not show abnormal effects so readily, but narrowing of the leaves of grasses due to growth regulators has been observed and the fusion of the leaf blade margins to give a tubular leaf is a common occurrence in cereals. This " onion " leaf encloses and traps the shoot, which, if it is to emerge, has to burst out of the side.

ROOT DISTORTIONS

Exposure to synthetic growth regulators may result in the stunting of roots, excessive branching, and excessive production of root hairs. The production of roots on the stem has already been mentioned. There may be malformation of storage roots, as described by Nielsen (1951), with irregular growth and constrictions, much greater production of side roots, scabbing and splitting of the surface, and tumour formation. Sometimes several shoots develop from the crown of the root (for example, in sugar beet and carrot) in place of the normal single shoot.

MALFORMATION OF FLOWERS

Flower sepals and petals can undergo the same malformation of shape as described for leaves. Fusion of various flower parts may occur and give rise to blooms highly irregular in appearance. Flower stalks and their accompanying flowers can also fuse to produce a fasciated effect. As a result of these and other abnormalities the flower is often sterile.

Changes induced in the graminaceous inflorescence have been studied in some detail in cereals (Pedersen *et al.*, 1948 ; Large and Dillon Weston, 1951). A variety of effects involving irregular placement of spikelets, supernumerary spikelets and kernels, branching, etc., can be produced.

EFFECTS ON FRUIT

Synthetic growth regulators are well known for their ability to induce parthenocarpy in fruits. Such parthenocarpic fruits may be irregular in shape, as in the well-known plum-shaped fruit induced in tomatoes, and may occur as a result of damage. Arising out of damage to the flower, fused fruit-stalks and fruits may occur, the latter then being most irregular in shape.

The foregoing general descriptions only outline the wide variety of morphological effects which can be caused accidentally by synthetic growth regulators. Individual compounds vary considerably in their ability to produce these malformities : for instance, of those growth regulators used as herbicides, 2, 4–D is much more active than MCPA or 2, 4, 5–T in causing formative effects on foliage over a wide range of species. A categorical diagnosis of growth-regulator damage cannot be made in many instances. The time lag between exposure to the chemical and the appearance of morphological effects may often make the tracing of the source of contamination difficult. Finally,

it must be pointed out that some effects almost identical with those described can be induced by high dosages of certain organo-phosphorus insecticides (McIlrath, 1950 ; Hall, 1951) and by extreme environmental conditions, as in high temperature and low light intensity in experiments briefly mentioned by Osborne and Went (1953).

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SURVEYS FOR CHOKE (*EPICHLOE TYPHINA*) IN COCKSFOOT SEED CROPS, 1951–53

Contribution from the Conferences of Plant Pathologists and Grassland Officers, National Agricultural Advisory Service, compiled by E. C. Large of the Plant Pathology Laboratory, Harpenden

In continuation of the work started in 1951 (*Plant Pathology*, **1**, 23–8) an *extensive* survey of the incidence and severity of choke was made on 776 of the seed crops of Aberystwyth strains of cocksfoot entered for inspection in 1952, and on 609 of those entered in 1953. In addition, and again as in 1951, an *intensive* survey (with tiller counts) was made by the plant pathologists on about 10 per cent of the crops surveyed by the inspectors in the extensive survey; that is, on 72 crops in 1952 and 68 crops in 1953. The surveys were carried out in collaboration with the Welsh Plant Breeding Station, and the organization of the work, and methods used, were the same as in 1951. Observations on a few crops of cocksfoot of other than Aberystwyth strains were made in 1952, and in that year also information was collected on the actual yield of seed from fifty of the crops included in the intensive survey of 1951. This contribution gives the results obtained in 1952 and 1953 in the same form as in 1951, and summarizes the results of the survey as a whole over the three years.

TABLE 1

EXTENSIVE SURVEY. OCCURRENCE AND SEVERITY OF CHOKE IN 776 COCKSFOOT SEED CROPS IN 1952 AND 609 CROPS IN 1953. ENGLAND AND WALES

(*a*) In relation to harvest year (all strains)

No. of Crops with Choke	*1st Year*		*2nd Year*		*3rd Year*		*4th Year*		*5th–7th Years*	
	1952	1953	1952	1953	1952	1953	1952	1953	1952	1953
Severe ..	—	—	—	2	4	3	1	—	3	—
Frequent ..	1	—	7	14	35	17	9	9	—	2
Occasional ..	3	6	78	67	66	94	8	19	7	4
Absent ..	242	84	238	177	61	100	10	10	3	1
	246	90	323	260	166	214	28	38	13	7

(*b*) In relation to strain (all harvest years)

No. of Crops with Choke	*S.26*		*S.37*		*S.143*		*All Strains*	
	1952	1953	1952	1953	1952	1953	1952	1953
Severe	4	1	1	1	3	3	8	5
Frequent	14	12	12	10	26	20	52	42
Occasional	33	48	49	51	80	91	162	190
Absent	183	110	136	88	235	174	554	372
	234	171	198	150	344	288	776	609

(*c*) In relation to province (1952 and 1953)

No. of Crops with Choke	*Northern*	*Yorks & Lancs*	*East Midlands*	*West Midlands*	*Eastern*	*South-Eastern*	*South-Western*	*Wales*
Severe	2	—	—	3	3	3	2	—
Frequent ..	2	—	10	23	43	12	4	—
Occasional ..	3	2	20	132	125	59	10	1
Absent	8	13	109	311	282	136	61	6
	15	15	139	469	453	210	77	7

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Choke in Cocksfoot Seed Crops

Examination of the results given in Table 1, together with those in the corresponding table for 1951 (*ibid*, **1**, 25), shows that the extensive survey over the three years indicated no appreciable difference in the incidence of choke on the three strains of the grass, or in the different provinces. There was no outstanding seasonal difference in severity or incidence of the disease over the three years. The main factor affecting the incidence of choke was undoubtedly the age of the stand. The overall results of the extensive survey may therefore be fairly summarized, as in Table 2, by taking together all the 2,029 crops examined in the three years, to show the incidence of choke in relation to age of stand.

Table 2

Extensive Survey. Percentage of Crops in Each Harvest Year in which Choke was Reported to be Severe, Frequent, Occasional or Absent. 2,029 Crops. England and Wales, 1951–53

Choke	*1st Year*	*2nd Year*	*3rd Year*	*4th Year*	*5th–7th Years*	*All Years*
Severe	0·0	0·6	2·4	1·2	18·8	1·3
Frequent	0·5	4·9	13·9	26·5	25·0	6·9
Occasional ..	2·3	27·2	40·3	43·4	37·4	23·0
Absent	97·2	67·3	43·4	28·9	18·8	68·8
No. of Crops ..	654	783	461	83	48	2,029

The results of the intensive survey by the plant pathologists in 1952 and 1953 (Table 3) were closely in line with those obtained in 1951 (*ibid*, **1**, 26), and fully confirmed the finding in the extensive survey that the main factor affecting severity of choke was the age of the stand.

Table 3

Intensive Survey. Number of Cocksfoot Seed Crops in Each of Six Categories for Percentage of Choked Tillers. 140 Crops (72 in 1952, 68 in 1953). England and Wales

(*a*) In relation to harvest year (all strains)

Percentage of Choked Tillers	*1st Year*		*2nd Year*		*3rd Year*		*4th Year*		*5th–7th Years*	
	1952	1953	1952	1953	1952	1953	1952	1953	1952	1953
41–70	—	—	—	—	—	—	—	—	—	—
21–40	—	—	1	—	1	1	1	3	3	1
11–20	—	—	—	—	2	3	3	4	2	1
1–10	—	—	2	2	2	3	3	3	1	—
0·1–0·9 ..	—	1	3	3	2	2	4	2	1	—
nil	18	11	15	17	6	7	—	3	2	1
	18	12	21	22	13	16	11	15	9	3

(*b*) In relation to strain (all harvest years)

Percentage of Choked Tillers	*S.26*		*S.37*		*S.143*		*All Strains*	
	1952	1953	1952	1953	1952	1953	1952	1953
41–70	—	—	—	—	—	—	—	—
21–40	2	1	1	1	3	4	6	6
11–20	2	3	2	3	3	2	7	8
1–10	—	3	4	1	4	4	8	8
0·1–0·9	2	4	2	1	6	3	10	8
nil	12	9	14	15	15	14	41	38
	18	20	23	21	31	27	72	68

The intensive surveys indicated no consistent differences in susceptibility of S.27, S.36 and S.143 to choke ; although tiller counts were made on only four crops of cocksfoot of other than Aberystwyth strains (in 1952), the figures were such as might have been obtained for four crops of Aberystwyth strains (of corresponding years) taken at random. They were : Danish cocksfoot : second year, 0 per cent ; third year, 1 per cent ; third year, 3·5 per cent ; and Akaroa cocksfoot : third year, 10 per cent.

The results of the intensive surveys are summarized in Table 4. To facilitate comparison with those of the extensive survey (Table 2), all the 226 crops on which tiller counts were made in the three years are taken together to show the percentage of choked tillers in relation to age of stand.

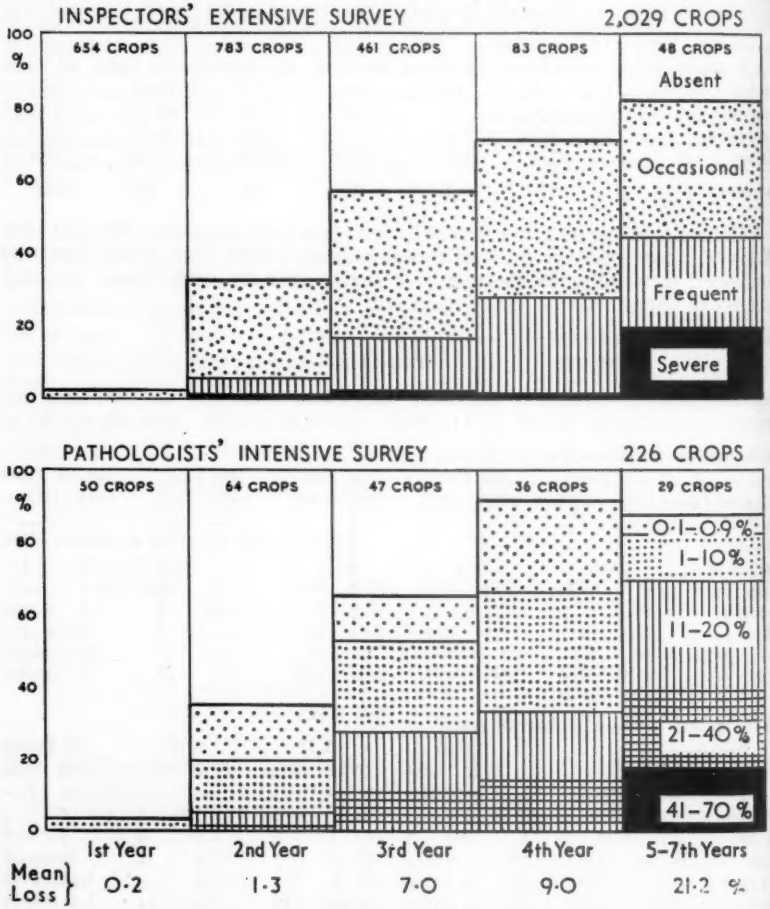

Fig. 1. Percentage of the crops in each harvest year falling into each category for incidence of choke in both the extensive and intensive surveys, 1951–53.

TABLE 4

INTENSIVE SURVEY. PERCENTAGE OF CROPS IN EACH HARVEST YEAR IN EACH OF SIX CATEGORIES FOR PERCENTAGE OF CHOKED TILLERS. 226 CROPS. ENGLAND AND WALES. 1951–53

Percentage of Choked Tillers	*1st Year*	*2nd Year*	*3rd Year*	*4th Year*	*5th–7th Years*	*All Years*
41–70	—	—	—	—	17·3	2·2
21–40	—	1·6	10·7	13·9	20·7	7·5
11–20	—	3·2	17·0	19·4	31·0	11·5
1–10	2·0	14·1	25·5	33·3	13·8	16·8
0·1–0·9	2·0	15·6	12·8	25·0	3·4	12·0
nil	96·0	65·5	34·0	8·4	13·8	50·0
No. of Crops ..	50	64	47	36	29	226

CORRESPONDENCE BETWEEN RESULTS OF EXTENSIVE AND INTENSIVE SURVEYS

In Fig. 1 the inspectors' assessments on the crops included in the extensive surveys in the three years, 1951–53, are compared with the plant pathologists' counts of choked tillers in the intensive surveys. The histograms in the figure show the close agreement between the main indications from the two types of survey. The inspectors' survey clearly revealed the trend of increase of choke with age of stand ; the plant pathologists' survey provided a quantitative estimate of the corresponding losses in terms of percentages of tillers choked and, therefore, inoperative for seed production. The plant pathologists' survey also provided a rough calibration of the inspectors' visual assessments of incidence. Fig. 1 shows that the range of incidence described by the inspectors as "occasional" corresponded very closely (except in the few 5th–7th year stands) to the plant pathologists' counts of 0·1 to 10 per cent choked tillers ; "frequent" corresponded to 11 to 40 per cent choked tillers ; and "severe" to over 41 per cent.

YIELDS OF SEED IN 1951

Yields were ascertained for 50 of the crops on which the plant pathologists made tiller counts in 1951. The yields were exceedingly variable, and obviously influenced by many more important factors than the incidence of choke. Grouped according to the percentage of choked tillers in the stand the mean yields were as follows :

Percentage of Choked Tillers	No. of Crops	Mean Yield of Seed per Acre
		cwt.
41–70	—	—
21–40	1	1·4
11–20	5	3·6 ± 0·6
1–10	12	4·0 ± 0·6
0·1–0·9	6	5·3 ± 1·3
nil	26	4·7 ± 0·5
All crops	50	4·4

It is evident that in this small sample of the crops there was no significant difference between the mean yields at levels of choke up to 11–20 per cent. It

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would appear that the effect of choke on the yield of seed was so masked by the effects of differences in cultivation, age of stand, soil fertility, weed competition and general management that yield figures from a number of different fields happening to have differing percentages of choked tillers are of little or no value for revealing the effect of choke on yield.

EFFECT OF CHOKE ON NUMBER OF FLOWERING TILLERS

In the absence of controlled experiments, the effect of choke on the yield of seed may be estimated by the method outlined in the previous contribution (*ibid*, **1**, 28). Scatter diagrams similar to that for 1951, relating number of flowering tillers per foot of drill with the percentage of choked tillers, were plotted for all the crops in the intensive surveys in 1952 and 1953. Again it was found that the mean total number of tillers (choked tillers + flowering tillers) per foot run of drill was approximately constant, whatever the level of choke. In other words, there was no evidence of any compensatory effect tending to increase the number of flowering heads when some of the tillers were choked, and no evidence of any systemic effect tending to decrease the number. Hence, and in the absence of any evidence that the yield of seed *per head* from apparently unaffected tillers on partly choked plants differs materially from that of those entirely healthy, it appears reasonable to assume that the loss from choke in any crop is what it appears to be ; for example, that 10 per cent of choked tillers in a crop represents a direct loss of 10 per cent of the seed, and *pro rata*. This is not to say that a crop having 10 per cent—or even 30 per cent or more—of choked tillers may not give a very good seed yield, perhaps far greater than that from some less vigorous crops quite free from choke. It is to say that the good yield would be better still if it were not for the presence of the disease.

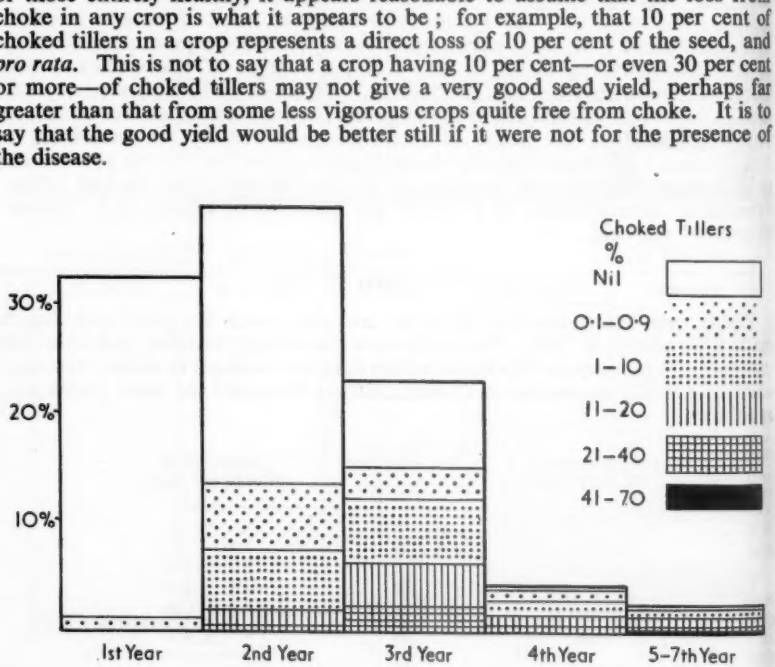

Fig. 2. Approximate percentage of total acreage in each harvest year, and incidence of choked tillers.

Choke in Cocksfoot Seed Crops

Economic Significance of the Disease

The approximate percentage of the total acreage accounted for by crops in each harvest year, and the mean incidence of choked tillers among them, is shown in Fig. 2. This diagram makes it clear that, although the proportion of choked tillers was high in the older stands, there were, in fact, so few of them that the total loss on this account was not very great.

Assuming, as has already been indicated, that the percentage loss of seed due to choke is directly represented by the percentage of choked tillers, the annual loss of seed yield due to choke for all the crops of cocksfoot entered for certification in England and Wales over the years 1951–53, has been shown by the surveys to have been about 3 per cent. This overall loss was made up by an average loss of about 21 per cent in the few crops in their fifth–seventh harvest year ; 9 per cent in fourth-year crops ; 7 per cent in third-year crops ; and 1·3 per cent in second-year crops. Except in one or two cases, losses in first-year crops were nil or negligible.

Many of the older crops, in which the greatest losses from choke occurred, were found in the course of the survey to have become unproductive for reasons other than choke, notably because of high infestation with weed grasses and soil impoverishment. The ploughing up of some of these unproductive old crops, which was one of the indirect results of the surveys, has given a slight reduction in the overall national loss due to the disease. The incidence, however, of 7 per cent mean loss in third-year crops, which are numerous and of considerable economic importance, fully justifies the continuance of research, by methods outside the scope of a national survey, into the transmission and etiology of choke.

This contribution concludes the account of these surveys begun in the previous article (*Plant Pathology*, 1952, **1**, 23–8), in which the organization of the work was described. The Conferences of Plant Pathologists and Grassland Officers take this opportunity of thanking all those who have collaborated in the course of the three years.

DISEASES AND PESTS ON HORTICULTURAL PLANTING MATERIAL

Under the F.A.O. Plant Protection Convention of 1951 (see this Journal, 1952, **1**, 14) each contracting government undertakes to make provision for an official plant protection organization, charged, among other things, with the inspection of growing plants and consignments of plants moving in international traffic. Officers responsible for such work in Britain are familiar with the symptoms of the diseases in the field, or have ready access to books that provide such information. They have felt the need, however, for a guide to the recognition of the same diseases and pests as they occur in the dormant or semi-dormant planting material encountered in import and export inspection work.

A handbook, prepared at the Plant Pathology Laboratory, Harpenden, Herts, to meet this need, was published by Her Majesty's Stationery Office in October 1953, under the above title, price 6s. (6s. 2d. by post). It contains 38 pages of text with concise working notes on the recognition of some three hundred diseases and pests, which are arranged under host plants. The 83 clear half-tone illustrations are indexed for easy reference.

Although intended primarily for inspectors, this handbook will undoubtedly be found useful by plant pathologists and entomologists in advisory, research and educational fields. It contains a great deal of diagnostic information in very concise form, but it confines itself exclusively to what may be seen on planting material in its dormant stage. With this limitation, it is a unique and inexpensive work of reference.

(61472) A** 2

OBSERVATIONS ON GREY MOULD IN STRAWBERRIES

by E. H. WILKINSON

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An unusually severe attack of Grey Mould (*Botrytis cinerea* Pers.) occurred on the strawberries—Royal Sovereign and Auchincruive Climax—at the college farm in 1953. The attack developed in mid-June, during a period when the weather was calm and cloudy and the humidity was abnormally high. There was heavy rain (0·65 inches) on June 11–12. On June 12 the mould was found on only a few bird-pecked fruits. On June 15, after three days with 9 a.m. relative humidities of 96, 99 and 92 per cent, slight, continuous rain, and minimum screen temperatures of 53–54°F., the infection had become widespread on both varieties and was giving cause for alarm. It was noted that the growth of mould often began on dead petals adhering to the fruit, or trapped between the fruit and the calyx. Among Royal Sovereign the mould also frequently started at points of contact between the fruit and the straw. The rows were heavily strawed and the plants were in their first fruiting year, having been planted in October 1951. The Climax plants were more upright, and as their fruit was then less fully developed than that of the Royal Sovereign, the contact with the straw was less. The humid conditions kept the straw and the dead petals continuously moist or wet.

By June 18 the estimated loss of crop due to the mould was at least 40 per cent in the Royal Sovereign, and 10 per cent in the Climax. The loss was increasing from day to day by the spread of contact infection, and it was decided to attempt to obtain some measure of control by picking off all diseased berries over the whole acre of Royal Sovereign and the two acres of Climax. This was done on June 20 and 22, with the help of students.

In the Royal Sovereign between 48 and 60 lb. of affected fruits were removed in each 70-yard row (equivalent to nearly 2 tons per acre, with 78 rows per acre). Some further infection developed, and as the sound fruit was picked diseased fruits were again removed, collected in separate chips and taken off the field. The cost of removing the diseased fruit was about £50 per acre. But even so high an expenditure as this was justified, as what threatened to be a total loss was avoided, and from the acre of Royal Sovereign 2¼ tons of sound fruit was picked, with a market value of about £365. In the two acres of Auchincruive Climax not more than 10 per cent of the fruit was removed as diseased, and over 3¼ tons per acre of sound fruit was harvested.

THE OCCURRENCE OF PEA WILT IN BRITAIN

by E. W. BUXTON

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AND I. F. STOREY

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Pea Wilt is a disease which is well known in America and on the Continent. In the literature it appears under several names, the most general of these being " St. John's Wilt ". This term, according to Wollenweber (1935), covers the whole of the pea failure complex due to a number of *Fusaria*. In America two distinct wilt diseases are recognized, mainly on the basis of pathogenicity : Pea Wilt, as described by Linford (1928) and attributed by him to *Fusarium orthoceras* var. *pisi*, and Near Wilt, caused by *Fusarium oxysporum* f. 8 (Snyder and Walker, 1935). In their revision of the Elegans section of the genus *Fusarium*, Snyder and Hansen (1940) renamed these two fungi *F. oxysporum* f. *pisi* race 1 and *F. oxysporum* f. *pisi* race 2, respectively. Recently Schreuder (1951) has reported the occurrence in Holland of *F. oxysporum* f. *pisi* race 1 and another *Fusarium* sp. morphologically similar but which is pathogenic to American pea varieties resistant to Pea Wilt ; he names this fungus *F. oxysporum* f. *pisi* race 3, and holds the view that it is equivalent to the " St. John's Wilt ", as described by Wollenweber (1935).

In Britain the presence of Pea Wilt as distinct from Foot Rot (attributed mainly to *Fusarium solani* var. *martii*) has not been recognized, though the occurrence of symptoms resembling those of " Near Wilt " was noted in Somerset in 1945 (Moore, 1948). In 1952 Dr. N. F. Robertson, in conjunction with one of us (E.W.B.), instigated an inquiry into the Fusarium complex associated with pea failures. In the spring of 1953 specimens were sent in (by I.F.S.) of wilted peas, variety Kelvedon Triumph, from Sweffling, Suffolk, showing symptoms in general agreement with those described by Linford (1928) (Plate I, 1), and in the early summer we visited pea-growing districts of Essex and Suffolk together, and made a search for other cases. Isolations were made (by E.W.B.) from the samples collected, and from material sent in from other districts by several Provincial Plant Pathologists of the National Agricultural Advisory Service.

SYMPTOMS

The majority of the diseased plants, like those from Sweffling, were rather stunted, with the lower and, nearly always, the upper leaves, beginning to turn yellow and roll under along their mid-veins. Such rolled leaves were brittle and easily detachable from the main stem. Yellowing was preceded by the appearance of a greyish bloom of the foliage. This wilting and yellowing occurred as the flowers were forming, and diseased plants rarely bore full pods. Patchiness of the crop was well marked in some cases, while in others lateral spread of the disease along the rows could be inferred and, rarely, isolated plants had been infected. Clear cases of mismanagement in agricultural practice—for example, three or four years of pea cropping with little break—had resulted in losses of almost the whole crop. The majority of cases, however, occurred where peas were being grown for the first time. Suspected cases of eelworm damage (*Ditylenchus dipsaci*) confused above ground with wilting symptoms, were not confirmed by entomologists of the N.A.A.S. at Cambridge.

The roots of the infected plants showed no external damage and the cortex was quite healthy. The vascular tracts of roots and, to some extent also, of the stems, were in the majority of cases discoloured, and they varied in colour from pale orange to deep brick-red. This discoloration extended through the root-stem transition zone into the stem, and in the most seriously infected plants the reddening extended the whole way to the growing points (Plate I, 2). Species of *Fusarium* were consistently isolated, as shown in Table 1, from such infected vascular tissue.

Later in the season specimens showing varying degrees of rotting of the root cortex were examined. In some of these cases reddening of the stele was also observed, and *Fusaria* were again isolated from both the vascular tract and from the cortex. Such symptoms, well known as Foot Rot and usually ascribed to *Fusarium solani* (Mart.) Sacc. var. *martii* (Appel & Wollenw.) Wollenw. f. 2 Snyder, appear in some cases to be due to secondary invasions of already wilted plants. In other cases, clear-cut symptoms of Foot Rot were observed and *Fusarium solani* alone was isolated.

ISOLATION AND IDENTIFICATION OF THE FUSARIA

From samples of pea plants exhibiting the symptoms described above, pieces of vascular tissue about 0·5 cm. long were surface-sterilized in 1 per cent silver nitrate solution, passed through a concentrated NaCl solution, and washed in sterile water. Table 1 shows the occurrence of root and stem symptoms and the species of *Fusarium* found when the fragments were plated on 2 per cent potato dextrose agar.

TABLE 1

ROOT AND STEM SYMPTOMS AND SPECIES OF FUSARIUM ISOLATED

Locality and Variety	Date	Root Cortex Rotted	Root Stele Red	Stem Stele Red	*Fusarium oxysporum*	*Fusarium solani*
Sweffling, Suffolk (K.T.) ..	May 29	—	+	+	+	−
Hatfield Peverel, Essex (L.S.) ..	June 9	−	+	+	+	−
Woodbridge, Suffolk (H.G.) ..	June 11	+	−	−	−	+
Rayne, Essex (Onward)	June 20	−	tr	tr	+	−
Hatfield Peverel, Essex (Onward)	June 23	−	+	+	+	+
Little Totham, Essex (Meteor) ..	June 23	−	+	+	+	−
Hemingford Grey, Hunts (K.W.)	June 24	−	+	+	+	−
Shardlow, Derby	July 2	+	+	−	−	+
N.I.A.B., Cambs (Onward) ..	July 6	−	+	+	+	−
Rickling, Essex (Onward) ..	July 6	−	+	+	+	−
Sandy, Beds (Onward)	July 7	+	+	−	−	+
Grantham, Lincs	July 15	tr	+	+	+	+
Langtoft, Lincs (K.W.)	July 15	tr	+	+	+	−
Langtoft, Lincs (Onward) ..	July 15	tr	+	+	+	+
Kesteven, Lincs	July 15	+	tr	tr	+	+
Littlebury, Essex	July 15	tr	+	+	+	+
Hayling Island, Hants (Onward)	July 17	−	+	+	+	−
Biggleswade, Beds (Onward) ..	July 21	+	+	+	+	+
Saxham, Herts	July 21	tr	+	+	+	−
Colnebrook, Bucks (Onward) ..	July 21	−	+	tr	+	−
Evesham, Worcs	July 24	tr	tr	tr	+	+
Harpenden, Herts	Aug. 28	+	tr	−	+	+

K.T. = Kelvedon Triumph. L.S. = Laxton Superb. H.G. = Harrison's Glory.
K.W. = Kelvedon Wonder. Where the variety is not stated it is not known. tr = trace.

Between 7 and 60 fragments of root and stem vascular tissue were plated from each sample, according to the amount of the material available ; and, of the 452 fragments, 381, or about 84 per cent, yielded *Fusarium*. The majority of the isolates proved to belong to *Fusarium oxysporum* Fr. emend. Snyder & Hansen. Sample isolates were sent to Dr. W. L. Gordon of Manitoba who kindly confirmed the identifications. The first isolates (from the plants at Sweffling, Suffolk) showed a high proportion of *Fusarium oxysporum* var. *redolens*, which Gordon retains as a split from Snyder and Hansen's species *Fusarium oxysporum*. It is distinguished by its buff colour on potato dextrose agar and by slight differences of macrospore measurements and shape. This identification is particularly interesting, since Wollenweber (1935) mentions *Fusarium redolens*, which is synonymous with Gordon's *Fusarium oxysporum* var. *redolens*, as one of the causal organisms of " St. John's Wilt " in Europe. The later isolates, particularly those from roots showing cortical rotting, proved to be mixtures of *Fusarium oxysporum* and *Fusarium solani*, and in one case all three of the above-named *Fusaria* were clearly identified growing from one point of one root fragment. The position as regards relative pathogenicity of these three *Fusaria* is not at all clear, and we have here only a tentative suggestion of any temporal or spatial relations between them. However, it is fairly clear from Table 1 that, in general, *Fusarium oxysporum* can be found in the diseased tissue of the stele more often than *Fusarium solani*, and, moreover, it is present earlier in the season.

PATHOGENICITY OF THE ISOLATES

As isolates became available, small-scale pathogenicity tests were carried out in the Botany School, Cambridge. Isolates of *Fusarium oxysporum* were grown in 3 per cent corn-meal sand, and a pinch of this, diluted one-in-four with clean sand, was placed beneath each pea seed on planting in unsterilized John Innes potting compost. Symptoms closely resembling those seen in the field were reproduced. Three pea varieties and five *Fusarium* isolates were used in these tests. Further specimens of peas of variety Kelvedon Triumph were grown in boxes of soil taken from beneath diseased peas from the field, and the symptoms produced were identical with those shown by the original field specimens (from Biggleswade, Beds, July 21). It is too early to draw any very definite conclusions from these tentative beginnings, which were necessarily undertaken at the end of the season. It is hoped to repeat field and glasshouse experiments early next season, but already it is evident that *Fusarium oxysporum* has been demonstrated to be a causal organism of Pea Wilt in Britain.

TABLE 2

PREVIOUS CROPPING OF FUSARIUM-AFFECTED FIELDS

	1948	1949	1950	1951	1952
Sweffling	Cereal	Sugar Beet	Barley	Barley	Barley
Hatfield Peverel	—	*PEAS*	Wheat	Potatoes	Barley
Hatfield Peverel (Onward) ..	—	*PEAS*	Barley	Wheat	Potatoes
N.I.A.B.	—	Potatoes	Wheat	Wheat	Barley
Rickling	Cereal	Cereal	Potatoes	Cereal	Cereal
Biggleswade	Sage	*PEAS*	*PEAS*	Onions	Onions
Langtoft (K.W.)	*PEAS*	—	—	—	—
Littlebury	*PEAS*	Wheat	Barley	—	Barley
Hayling Island	Vegetables	Vegetables	Vegetables	Vegetables	*PEAS*
Saxham	—	—	Sugar Beet	Wheat	Oats
Evesham	—	—	—	Cereal	Cereal

EFFECT OF PREVIOUS CROPPING WITH PEAS

The cropping history, where it could be ascertained, for the fields referred to in Table 1, is given in Table 2. No evidence was obtained of any relationship between the incidence of wilt due to *Fusarium* and previous cropping with peas in the field affected. Those fields which had borne pea crops within the previous five years were no more numerous than those which had been free from the crop. The possibility that wilting might have been due to seed infection was tested in the Sweffling case, but no *Fusarium* was isolated from the sample pea seed. Seed transmission of the disease has, however, been demonstrated in Holland by Kerling (1952).

CONTROL MEASURES

No work has been done in Britain on the possibility of control of this disease. Dutch and American workers have found that the organism can survive for a number of years in the soil, and although our own relatively few observations on cropping history do not bear it out, it appears that crop rotation proves, at least in Holland and America, to be an important and fairly simple measure of control.

As in the case of most soil-borne *Fusarium* diseases, perhaps the best method of control is by the breeding of resistant varieties of the host plant. Varietal tests of resistance in glasshouse trials have been carried out to a certain extent by Cruickshank (1951) in New Zealand, and it is hoped that facilities may become available for a testing and breeding programme in this country. Many of the popular pea varieties, including Laxton's Superb, Onward and Meteor, are reported as being susceptible to the disease.

Thanks are due to all those members of the N.A.A.S. who helped in the search for affected crops, or kindly forwarded diseased specimens for examination. One of the authors (E.W.B.) wishes to thank the Agricultural Research Council for a Research Studentship, during part of the tenure of which this investigation was carried out. Thanks are also due to Mr. F. T. N. Elborn for the photographs.

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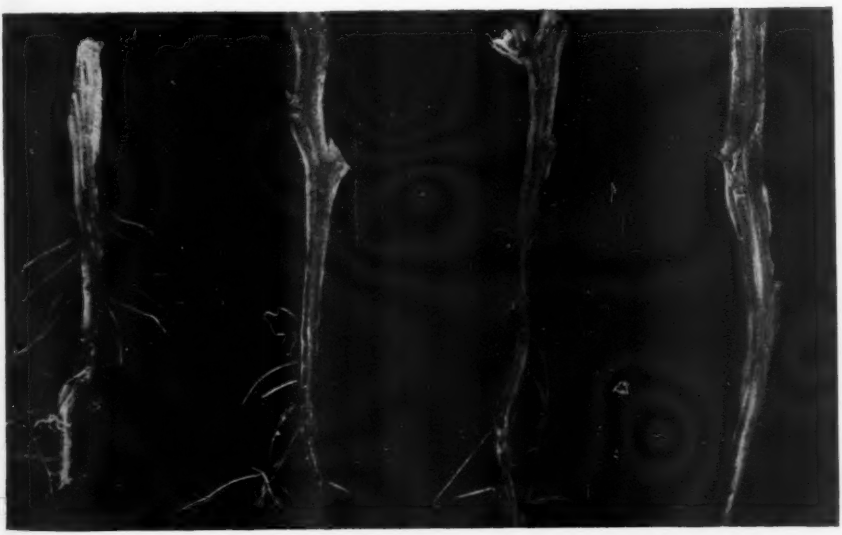
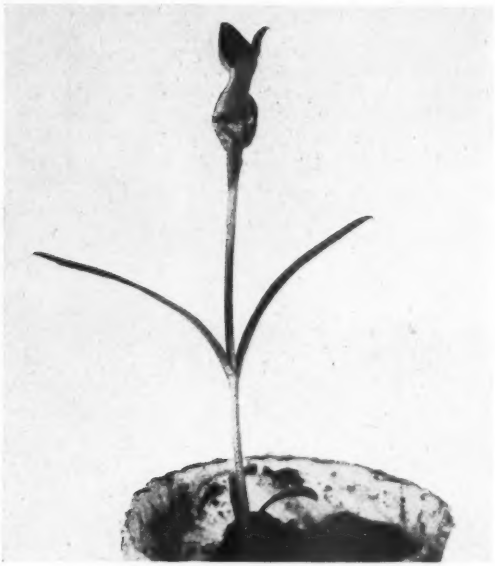
1. Pea plants, var. Kelvedon Triumph. *Left*: Healthy. *Right*: Showing wilt caused by *Fusarium oxysporum*. Sweffling, Suffolk, May 29, 1953.

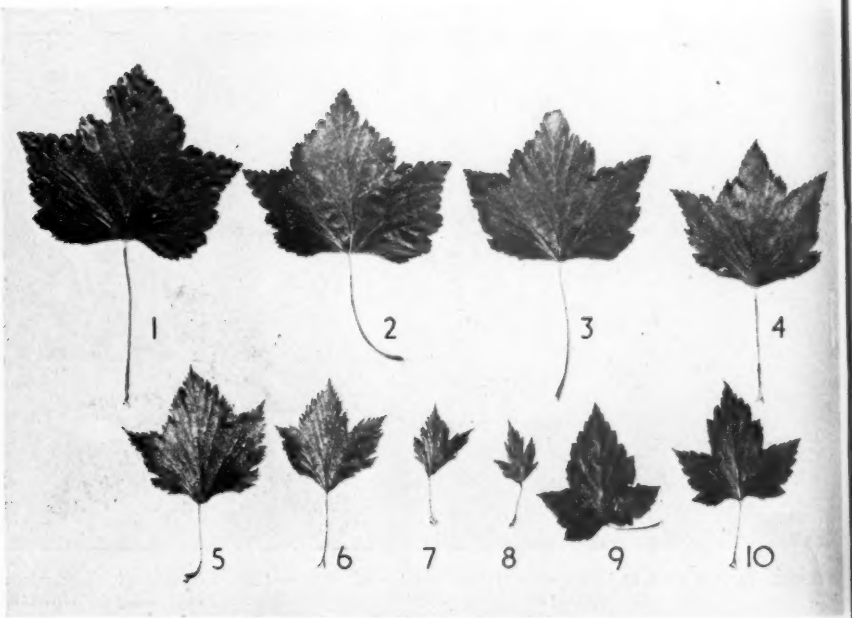


2. Lower parts of stem and root showing wilt symptoms. The steles were reddened, the cortices quite clean. *Three on left*: Kelvedon Triumph, Sweffling, Suffolk, June 11, 1953. *Right*: Onward, Hayling Island, Hants, July 15, 1953.

PLATE I



1. Drummond phlox showing cup-shaped composite leaf.



2. Leaves from young basal shoot of black currant, in sequence from base (1) to tip (10), showing effect of 2, 4-D amine treatment in previous year.

PLATE II

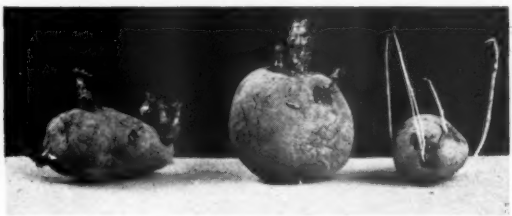
1. Marigold showing leaf fusion and contortion.

2. Terminal shoot of tomato four weeks after treating the leaf below the lowest shown with 0·5 microgrammes of 2, 4-D amine.

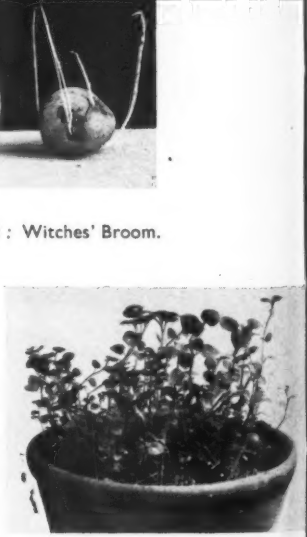
PLATE III

1. Wilding, showing simplified leaves with enlarged terminal leaflets and many stems.

2. Witches' Broom. Early symptoms: marginal flavescence and down-curving of rachis and lamina (here shown on tomato).



3. Sprout characters.
Left: Wilding. *Centre*: Normal. *Right*: Witches' Broom.



4. *Left*: Witches' Broom. Early symptoms on potato: spindly stems hanging from a potted plant, showing bushy growth, marginal flavescence and aerial stolons.

5. *Above*: Witches' Broom. Dwarf stems from second generation of very numerous small tubers produced by a single plant.

PLATE IV

POTATO WILDINGS AND WITCHES' BROOM IN SCOTLAND

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Some confusion is evident from the literature regarding the status of potato wildings and witches' broom in Scotland. Despite emphasis by McIntosh (1940) that the two conditions are distinct, Murphy and McKay's (1932) assertion that "wilding" is synonymous with "witches' broom" continues to be upheld. The purpose of this article is to review the present standing of the two diseases and to point out their respective affinities.

WILDINGS

Wildings—whose name derives from a fancied reversion to wild type (*vide* Cuthbertson, 1952)—differ from normal plants in having a compact, bushy habit of growth with numerous, often thin, stems and many relatively undersized tubers. The secondary leaflets are rudimentary and there are fewer and more rounded primary leaflets than usual, the terminal one being enlarged and obvious (Plate IV, 1). Flowers are rarely formed, even in free-flowering varieties. So great is the change of habit and so generally similar are all wildings that it is sometimes difficult to identify the variety to which a wilding belongs.

Wildings were first recognized about 1920 in the variety King Edward and were then thought to be rogues, supposedly the vegetative progeny of siblings of this variety. In the year after their discovery in King Edward, wildings were also noted in other varieties. In 1925, McIntosh (*in lit.*) showed by extensive grafting experiments that the condition was not transmissible. The mechanism whereby wildings are produced is not understood but, although many potato variants behave as if they were periclinal chimeras, wildings are not in this category (Whitehead, McIntosh and Findlay, 1945). Wildings produce more seed-size tubers than do normal plants and so can increase rapidly in a stock. Instances occur of non-certified stocks of standard varieties being composed largely of wilding plants.

WITCHES' BROOM

Whereas wildings are known with certainty only from the British Isles and Western Europe, witches' broom, first discovered in Montana in 1915, has been reported from North America, Australia, China, Italy, Japan, Poland, Russia and Scotland. In Scotland the disease was first seen in the early 1920s and named "witches' broom" by McIntosh (*in lit.*) after the appearance of Hungerford and Dana's (1924) account. Despite such world-wide distribution, detailed symptom records and accounts of experimental work on witches' broom have come only from the United States (Hungerford and Dana, 1924; Young and Morris, 1928; Young, 1929; Kunkel, 1943), Canada (Wright, 1952), Russia (Jaczewski, 1926) and Japan (Tanaka, 1953). From a study of these, it would seem that the disease is aetiologically complex.

In the north-west of the U.S.A. and in British Columbia the symptoms in potato are generally a dwarfing of the new leaves, which become upright, slightly rolled and show marginal flavescence, with a proliferation of dormant buds ultimately giving the plants a bushy appearance. The abnormal shoots

are slender with swollen nodes, wingless, round in cross-section, and bear small, simplified leaves with marginal flavescence of the leaflets. There is often profuse flowering and occasionally thin aerial stolons and aerial tubers are produced. Such plants yield a great number of small tubers, which if left *in situ* quickly sprout to form a mass of thin, flexuous stems with simplified leaves. Hair sprouts are produced by stored tubers. Tubers from witches' broom plants may, anomalously, be slow to germinate after planting (Murphy and McKay, 1932, working with American material) and there result dwarfed plants with trailing stems and simplified leaves ; there is a tendency for some stems to grow away and manifest milder disease symptoms (Young and Morris, 1928 ; Murphy and McKay, 1932).

The witches' broom of western North America has been transmitted by grafting to potato, tomato (Young and Morris, 1928 ; Wright, 1952), tobacco (Young, 1929) and *Cyphomandra betacea* (Wright, 1952). Incubation periods generally were very long, varying according to species and locality from about thirty days to a whole season. In tobacco, spindly branches bearing dwarfed flavescent leaves were produced. In tomato, according to Young and Morris (1928), the first symptom is a marginal flavescence of the new leaflets, together with dwarfing, rugosity, narrowing of leaflet blades and downward curling of leaflets and rachides. Similar symptoms were also recorded by Wright (1952) who, in addition, described a second syndrome in tomato, the distinguishing features of which are reduction in leaf size without severe distortion, and leafiness of sepals and petals coupled with sterility. Wright suggests affinities with tomato big bud virus for the second witches' broom virus, which is quite indistinguishable from the other in potato. *Cyphomandra betacea* is also an indicator host.

The British Columbian witches' broom virus or viruses could not be transmitted by dodder (*Cuscuta campestris*) from potato to potato, and no symptoms developed on tomato, tobacco, *Nicotiana rustica*, *N. glutinosa*, sugar beet, *Vinca rosea* and other plants following attempted virus transmission by this means.

Kunkel (1943) worked with a potato witches' broom virus from Maine, which he obtained, according to Folsom (1946), from a potato plant showing " yellow top "—a symptom often claimed to be caused by aster yellows virus. However, as the virus Kunkel worked with was evidently not that of Aster Yellows, it is probable that his material represented the authentic potato witches' broom of Maine. The secondary symptoms described and illustrated by Kunkel (1943, 1952) closely resemble those of the comparable phase of the disease in the west. Kunkel found, however, that the Maine virus could be transmitted through dodder to potato, tomato, *Nicotianag lutinosa*, *N. rustica* *Vinca rosea* and sugar beet, in all of which witches' broom symptoms developed. These properties distinguish the Maine virus from the western form.

In Russia (Jaczewski, 1926) the symptoms of witches' broom resemble some of those described from western North America, the principal differences being that in Russia affected plants do not flower and few, very small, tubers are formed. Stunting and chlorosis are not constant features of the disease.

WITCHES' BROOM IN SCOTLAND

In Scotland, witches' broom occurs sporadically, and though it is often discoverable on certain farms and in some stocks, it is rarely present in any crop as a calculable percentage. The early symptoms of slight upward rolling

and flavescence of the apical leaves have seldom been seen and there is no field record of profuse axillary bud proliferation at this stage ; neither has Scottish material been known to flower excessively. Usually the first indication of witches' broom in a field is the presence of seemingly "drawn" plants, each having several stems with simplified leaves showing marginal flavescence. Tubers from such plants develop hair sprouts from every eye (Plate IV, 3) and, if planted in the normal way, produce late-appearing, many-stemmed dwarf plants with simplified leaves bearing marginal flavescence in varying degrees. Cockerham (*in lit.*) has found that such plants, if not unduly overshaded, eventually grow larger. The vegetative progeny sometimes repeat the symptom sequence shown by the parent plant but often they attain average height, differing from the normal in producing many small stems late in the season, in yielding numerous small tubers and, occasionally, in showing marginal flavescence and other less definable leaf symptoms.

In transmission experiments at East Craigs, dwarfed witches' broom shoots of the variety Kerr's Pink were grafted to young shoots or sprouts of several British varieties. In keeping with the experience of the American workers, the incubation periods were found to be long and, indeed, no symptom was observed on current growth, except on some plants caused to produce second growth through cutting back. On some of these plants there was eventually a mass of thickly proliferated stems bearing simplified leaves with marginal flavescence and, on the older parts, nodal bunches of much-branched aerial stolons (Plate IV, 4), rather as described by Wright (1952). The tubers from grafted plants produced thin-stemmed plants with simplified leaves having some marginal flavescence. These plants in turn formed many very small tubers which, if left unharvested in the plant pot, quickly produced a mass of chickweed-like growth (Plate IV, 5) from which a few stems tended gradually to assume an appearance nearly normal for the variety concerned. As already noted, similar lessening of symptom severity has been observed by other workers, but its significance is yet unexplained. This tendency to " recover " may be responsible for seemingly anomalous results which so far have been obtained in heat-treatment experiments designed to compare witches' broom as found in Scotland with that of Kunkel (1943), which responds to heat treatment.

The virus of the Scottish form of witches' broom has been transmitted by grafting to tomato and *Nicotiana glutinosa*, from which it was recovered again in potato. Symptoms were not seen in *N. glutinosa*. In occasional tomato plants marginal flavescence and downward curling like that described by Young and Morris (1928) have been observed following an incubation period of at least three months, and only after cutting back once or even twice (Plate IV, 2). No symptoms appeared on grafted plants of *Solanum demissum* and tobacco during a normal growing season.

DIFFERING FORMS OF WITCHES' BROOM

The virus of the witches' broom found in Scotland differs from the two viruses of western North America with respect to symptoms on tobacco and tomato, and in details of symptom expression on potato. The Scottish and originally-described American diseases seem particularly close, and the differences noted may be due merely to the use of dissimilar host plant varieties in the two countries. The Scottish and Maine viruses differ in their reactions on *Nicotiana glutinosa*. All the observed forms of the disease are closely analogous and, excepting the matter of precedence, have nearly equal claims to be called " witches' broom ". It would seem that there are at least five distinct forms of

the disease in potato : namely, the potato witches' broom of Hungerford and Dana (1924), Young and Morris (1928) and, in part, Wright (1952) ; potato witches' broom of Wright (1952) in part ; potato witches' broom of Kunkel (1943) ; potato witches' broom as found in Scotland, including the " wilding " of Murphy and McKay (1932) ; and the alfalfa witches' broom of Kunkel (1952). The potato witches' broom of Jaczewski (1926) may be yet another form. All the forms in potato are relatable to a group of viruses with leafhopper vectors, and the tendency is therefore to seek the vector among the Jassidae. Tests by Wright (1952) with *Macrosteles divisus*, *Colladonus geminatus* and *Circulifer tenellus* were negative, as also were those carried out with the aphids *Myzus persicae* and *M. pseudosolani*.

DISTINCTION BETWEEN WILDINGS AND WITCHES' BROOM

Witches' broom disease resembles the wilding condition only in that in both there are simplified leaves and many stems (an inconstant feature in the Scottish form of witches' broom). The marginal flavescence of witches' broom is not seen in wildings. The confusion initiated quite accidentally by Murphy and McKay is simply explained. Their request for wilding material from Scotland was made towards the end of a growing season, and a plant, the foliage of which was dead, was selected as being " probably a wilding ", having many stems. This plant was, as it happened, undoubtedly infected with witches' broom virus.

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TOMATO LEAF MOULD : SPRAYING TRIALS IN LANCASHIRE AND YORKSHIRE, 1949–52

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Tomato Leaf Mould (*Cladosporium fulvum* Cooke) causes loss every year in nurseries in Yorkshire and Lancashire, and in some seasons, particularly in Lancashire, the attack reaches its peak quite early, that is, in July. Growers appreciate that cultural factors, particularly ventilation, heating and watering, greatly influence the severity of the epidemic, but often it is not possible to carry out all the cultural measures of control that are desirable, and resort has to be made to spraying. Salicylanilide (Smith, *Gdnrs' Chron.*, 1933, **93**, 46–7) was first used. It gives fairly good control, and though it was not regarded as sufficiently effective in Lancashire it is still used there, and to a greater extent in Yorkshire, where attacks are usually less severe. In Lancashire, following the Cheshunt recommendation (Orchard, *Rep. exp. Res. Sta. Cheshunt*, 1933, 77), a combination of a colloidal copper fungicide with an oil emulsion was extensively used. This gives good control, but it was found that there is a tendency for the oil to cause oedema in varieties like Potentate, with resulting loss from Botrytis. The trouble was not experienced when a synthetic wetter was substituted for the oil.

To study the degree of control of Leaf Mould obtainable by spraying with some of the newer fungicides, and to compare their performance with that of colloidal copper and oil, trials were laid down in 1949 and continued until 1952 on varieties other than Potentate, and in houses where the disease was likely to appear. In general, four or five applications were given, starting in June. Fortnightly assessments were made of the progress of the disease on the foliage in the sprayed and unsprayed plots, using the key given below, which was developed by the Disease Assessment Committee of the Conference of Advisory Plant Pathologists. The method has been used by a number of observers and their results have been found to be in close agreement.

KEY FOR TOMATO LEAF MOULD

per cent	
0·1	Lesions found with difficulty, and on less than one plant in fifty.
1	Lesions on most plants, but only on a few leaves.
5	Lesions on every plant, and on most leaves except the young ones, but only about two to ten spots per leaf.
10	All except the youngest leaves affected, with ten to fifty spots per leaf.
25	All except the youngest leaves affected, but with about three-quarters of the leaf area green, although lowest leaves may be severely attacked.
50	All leaves affected. Most of the middle leaves show only half their area green.
75	All leaves affected. Most of the middle leaves show only one-quarter of the leaf green, giving a grey appearance to the crop as a whole.
90	Very little green visible on middle and lower leaves, but youngest leaves show green.
100	All leaves completely covered with lesions.

Randomized block trials, with four replications of each of four treatments and control, were carried out both in Lancashire and in Yorkshire each year from 1949 to 1951, and in Lancashire alone in 1952. In addition, a number

of pilot trials on single plots were also made in some of the years. Each plot consisted of about thirty plants and required 2 gallons of spray fluid. The materials included in the replicated block trials—in groups of four, as shown in the individual tables of results—were as follows, the amounts given being in all cases for 100 gallons of spray fluid :

Colloidal copper and oil	2½ pints of colloidal copper compound (Bouisol) and 1 gallon of white oil emulsion (Volck).
Colloidal copper and wetter ..	2 pints of colloidal copper compound with 4 ounces of synthetic wetter (Agral).
Salicylanilide	25 ounces of a dispersible powder containing 50 per cent salicylanilide (Shirlan).
Zineb suspension	25 ounces of a preparation containing 65 per cent zinc ethylene *bis* (dithiocarbamate) in the form of a dispersible powder (Dithane Z.78).
Nabam alone	94 fluid ounces of a liquid preparation containing 19 per cent disodium ethylene *bis* (dithiocarbamate) (Dithane D.14).
Nabam and zinc sulphate (*a*) ..	As " nabam alone ", but with the addition of 19 ounces of zinc sulphate.
Nabam and zinc sulphate (*b*) ..	59½ fluid ounces of a liquid preparation of disodium ethylene *bis* (dithiocarbamate), as used for " nabam alone ", with 21 ounces of zinc sulphate.
Ziram	37½ ounces of a zinc dimethyldithiocarbamate preparation (Zerlate).
Thiram	50 ounces of a tetramethyl-thiuram-disulphide preparation (Tulisan).
Glyoxalidine	27½ fluid ounces of a glyoxalidine preparation (Crag 341).

All the materials used in the main trials in 1949 (Table 1) gave a good measure of control, but the colloidal copper was notably less effective with a synthetic wetter than with oil emulsion at both centres. Salicylanilide was slightly more effective than colloidal copper and oil in Yorkshire and slightly less effective in Lancashire. The zineb treatment gave the best control at both centres, but the suspension used left a considerable deposit, which necessitated wiping the fruit. The deposits left by salicylanilide and by the colloidal copper were both very slight.

In addition to the replicated-plot trials in 1949, a number of pilot trials on single plots were carried out at two centres in Lancashire and three in Yorkshire. The treatments included all those in the main trials and also : 1½ lb. of a cuprous oxide preparation (Perenox) per 100 gallons ; Bordeaux mixture 5 : 7½ : 100 ; 4 pints of a liquid copper fungicide (Fungex) per 100 gallons, with and without 1 gallon of white oil emulsion (Redomit) ; 2 pints colloidal copper compound per 100 gallons without wetter ; and 25 ounces of copper 8-quinolinolate (Bioquin 1) per 100 gallons. All these copper fungicides gave a reasonably good control of Leaf Mould, but none was superior to colloidal copper and oil. As in the main trials, the zineb suspension gave more lasting protection than any of the other treatments.

In 1950 (Table 2) freshly precipitated zineb (nabam and zinc sulphate) was substituted for the zineb suspension used in 1949, with the aim of reducing the deposits left on the fruit.

Thiram (TMTD) was brought into the trials in this year.

Spraying against Tomato Leaf Mould

Table 1

Results of Replicated-Plot Trials in 1949

Tarleton, Lancs. Variety: Market King. Sprayed on June 23, July 6 and 22, August 4 and 18.

	Mean Percentage Leaf Mould					
	July 22	*Aug. 4*	*Aug. 18*	*Sept. 1*	*Sept. 21*	*Oct. 3*
Colloidal copper and oil	0	0·1	1·0	0·9	2·8	4·0
Colloidal copper and wetter ..	0	0·1	1·5	3·0	10·0	15·0
Salicylanilide	0	0·3	0·6	1·0	4·5	4·5
Zineb suspension	0	0·1	0·1	0·8	1·8	2·6
Unsprayed controls	0·5	1·8	8·4	19·0	30·0	57·0
Significant difference (P = 0·05) ..					1·9	

Cottingham, Yorks. Variety: Scarlet Globe. Sprayed on June 15 and 29, July 14 and 29, and August 12.

	Aug. 12	*Aug. 26*	*Aug. 30*	*Sept. 6*	*Sept. 19*	*Sept. 30*
Colloidal copper and oil	0·1	0·3	0·3	0·1	2·8	5·0
Colloidal copper and wetter ..	0	0·3	0·1	0·5	5·8	8·8
Salicylanilide	0·1	0·1	0	0·1	0·3	2·0
Zineb suspension	0	0	0	0·1	0·1	1·1
Unsprayed controls	0·1	1·0	0·5	0·5	11·1	21·2
Significant difference (P = 0·05) ..					2·1	

Table 2

Results of Replicated-Plot Trials in 1950

Tarleton, Lancs. Variety: Market King. Sprayed on June 7 and 21, July 7 and 21.

	Mean Percentage Leaf Mould					
	June 7	*June 21*	*July 7*	*July 21*	*Aug. 3*	*Aug. 17*
Colloidal copper and oil	0·5	3·0	4·2	28·7	23·2	17·5
Colloidal copper and wetter ..	0·5	3·5	5·0	35·0	25·0	16·2
Nabam and zinc sulphate (*a*) ..	0·5	3·2	1·2	1·0	1·0	5·5
Thiram	0·4	2·5	6·2	33·7	27·5	15·0
Unsprayed controls	0·4	3·7	22·2	78·7	—	—

Riccall, Yorks. Variety: Clibran's Victory. Sprayed on June 16 and 28, July 14 and 27, and August 10.

	July 27	*Aug. 10*	*Aug.* 30	*Sept. 12*	*Sept. 27*	*Oct. 11*
Colloidal copper and oil	0	0	0·1	0·1	0·1	1·0
Colloidal copper and wetter ..	0	0	0	0·4	1·3	2·2
Nabam and zinc sulphate (*a*) ..	0	0	0	0	0	0
Thiram	0	0	0	0·1	0·1	0·8
Unsprayed controls	0·1	0·1	0·4	1·4	4·5	6·2

In the exceptionally severe attack at the Lancashire centre in 1950 the nabam and zinc sulphate treatment gave outstandingly good control, and this was maintained up to the end of the season. There was little to choose between the other three treatments. At the Yorkshire centre the attack was slight and all the treatments gave good control, with nabam and zinc sulphate the best. The thiram proved a very safe spray and left no appreciable deposit on the fruit. The substitution of freshly precipitated zineb (nabam and zinc sulphate) for the zineb suspension much reduced the deposits on the fruit where this material was used.

In the trials at three centres in 1951 (Table 3) colloidal copper with wetter was omitted, and a preparation of ziram (zinc dimethyldithiocarbamate) was brought in, as it was thought that the use of this material might overcome the need for making up the nabam zinc sulphate mixture on the nursery, and the consequent risk of scorch if insufficient zinc sulphate were used. At one of the centres (Lancashire) the nabam solution was used without zinc sulphate to permit observations on scorching.

In 1951 the attack of Leaf Mould was not heavy at the Tarleton and Cottingham centres but it was severe at Pickering. At all three centres the nabam and zinc sulphate treatment gave almost complete control throughout the season. The nabam alone, without zinc sulphate, also gave excellent control at the one centre at which it was tried, but there was severe scorching of the foliage. There was some slight leaf scorching by nabam, even with zinc sulphate, at the Cottingham centre. Of the other materials, thiram gave as good control as colloidal copper and oil, but the ziram was slightly less effective.

TABLE 3

RESULTS OF REPLICATED-PLOT TRIALS IN 1951

Tarleton, Lancs. Variety: Market King. Sprayed on June 8 and 21, July 5 and 19, and August 2.

	Mean Percentage Leaf Mould					
	July 5	*July 19*	*Aug. 2*	*Aug. 16*	*Aug. 30*	*Sept. 13*
Colloidal copper and oil	0	0·1	0·3	0·8	4·0	8·8
Nabam and zinc sulphate (*a*)	0	0	0	0	0	0·3
Nabam alone	0	0·1	0·1	0·1	0·2	4·5
Ziram	0	0	0·1	1·0	3·8	10·1
Unsprayed controls	0·1	0·1	0·9	4·5	11·2	22·5

Cottingham, Yorks. Variety: E.S. 1. Sprayed on June 27, July 12 and 26, and August 9.

	June 27	*July 12*	*July 26*	*Aug. 9*	*Aug. 23*	*Sept. 7*
Colloidal copper and oil	0	0·1	0·3	1·8	2·5	6·8
Nabam and zinc sulphate (*a*)	0	0·1	0·1	0·4	0·8	0·1
Thiram	0	0·1	0·4	1·4	2·3	3·5
Ziram	0	0·1	0·5	1·5	3·3	10·0
Unsprayed controls	0	0·1	0·6	4·0	5·5	23·8

Pickering, Yorks. Varieties: Scarlet Knight and Plumpton King. Sprayed on June 18, July 3, 16 and 30.

	July 3	*July 16*	*July 30*	*Aug. 13*	*Aug. 27*	*Sept. 10*
Colloidal copper and oil	0·1	0·4	2·8	5·0	12·5	32·5
Nabam and zinc sulphate (*a*)	0·1	0·2	0·7	0·9	1·2	0·6
Thiram	0·1	0·6	2·5	5·5	16·8	32·5
Ziram	0·1	0·6	1·8	8·5	25·0	43·7
Unsprayed controls	0·1	1·2	4·6	17·5	40·0	60·0

By 1951 the efficacy of zineb (nabam and zinc sulphate) for the control of Tomato Leaf Mould was well established, but some growers still objected to the slight deposits on the fruit, and for that reason preferred colloidal copper with oil emulsion. In 1952 attempts were continued to find a form or compound of zineb that would not mark the fruit and not cause leaf scorch if wrongly made up. In the trial at one centre in Lancashire (Table 4) the nabam zinc sulphate treatment at reduced strength (*b*), and also glyoxalidine, were tested on replicated plots. In pilot trials on single plots in the same crop, nabam was

tried at strength (*b*) with 20 ounces of manganese sulphate substituted for the zinc sulphate ; and also with 10 ounces of hydrated lime substituted for the zinc sulphate. Thirty ounces per 100 gallons of copper zinc chromate (CR 658) was also tried.

In the 1952 trial the attack of Leaf Mould was fairly severe at first but it was checked by dry weather in August. The nabam zinc sulphate treatment gave excellent control at the strength used in previous years (*a*) and also at reduced strength (*b*). In the pilot plots the control was of the same order when manganese sulphate or lime was substituted for the zinc sulphate. There was some slight damage to the foliage by all the nabam mixtures but this was negligible. Glyoxalidine failed to control the disease, but the copper zinc chromate was promising. Neither of these substances caused any spray damage. Glyoxalidine left no visible deposits on the fruit, but the deposits from copper zinc chromate were considerable.

TABLE 4

RESULTS OF TRIALS IN 1952

Replicated-plot trials at Tarleton, Lancs. Variety : Clucas 99. Sprayed on June 10 and 24, and July 7 and 22.

	Mean Percentage Leaf Mould					
	June 10	*June 24*	*July 7*	*July 22**	*Aug. 7*	*Sept. 2*
Nabam and zinc sulphate (*a*) ..	0·3	1·9	4·3	1·5	1·3	2·1
Nabam and zinc sulphate (*b*) ..	0·4	2·3	2·0	3·8	1·3	2·4
Glyoxalidine	0·2	9·3	17·5	7·3	10·0	5·3
Unsprayed controls	0·3	8·0	27·5	9·0	15·5	8·3
Pilot trials on single plots in same crop, and sprayed on the same dates.						
Colloidal copper and oil	0·5	5·0	7·0	12·0	10·0	7·0
Nabam and manganese sulphate ..	0·2	1·0	3·0	5·0	5·0	2·0
Nabam and lime	0·1	5·0	4·0	2·0	0	5·0
Copper zinc chromate	0·2	3·0	8·0	7·0	8·0	5·0

* Reduction in the amount of Leaf Mould at this date was due to removal of some lower leaves throughout the crop in early July.

CONCLUSIONS

Under normal conditions when the Leaf Mould attack is slight or moderate almost any fungicide will give satisfactory control if the spraying is properly carried out and repeated a sufficient number of times. All copper fungicides are about equally efficient, but colloidal copper with a white oil emulsion is preferred as it leaves no visible deposits on the fruit.

Of the non-copper fungicides, salicylanilide and zineb (nabam and zinc sulphate) are outstanding, while thiram, glyoxalidine and ziram give some control. Ziram has the drawback that it leaves a heavy deposit on the fruit. Nabam with zinc sulphate was the only spray to remain efficacious in severe epidemics.

Thanks are due to the growers in Yorkshire and Lancashire who placed their glasshouses at our disposal for the trials, and to the horticultural staffs, particularly of J. W. Ewan in Lancashire, who made the preliminary arrangements at each centre. Most of the work of spraying each year was done by J. H. Bant, and others of my colleagues in Leeds who played a large part were A. R. Cottrell (1949–50) and D. Wiggell (1952).

TOBACCO NECROSIS VIRUSES AFFECTING TULIPS

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In 1948 I found that tobacco necrosis viruses, which appear to be soil-borne and are known to cause innocuous root infection of many different species of plants growing in greenhouses, were responsible for a lethal disease of forced tulips* which had then been noted in three different nurseries in England (Kassanis, 1949). Although tulip leaves could readily be infected by rubbing them with sap containing the viruses, I was unable to reproduce the extensive lesions that occur in naturally infected plants. This note reports further attempts to reproduce the disease by various methods of inoculation, together with further observations on its occurrence in England.

TRANSMISSION TESTS

For this work tulip bulbs were forced in large earthenware pots. Four bulbs were planted in each pot, and the pots were sunk in the ground and covered with 3–4 inches of soil. The pots were brought into the glasshouse when the bulbs had produced shoots about 2 inches long. All inoculations of plant tissue were made with inoculum containing " Celite " to facilitate transmission. The Rothamsted culture of tobacco necrosis virus was used ; the inoculum used was sap from infected tobacco leaves, as this is more infective than sap from diseased tulips.

During 1948–49 tests were made on Korneforos, Alberio, Rose Copland, and Bartigon. There were eight plants of each variety for each of four methods used. These were : inoculation of the leaves when 3–5 inches high on January 24 ; inoculation of the bulb scales immediately before planting on November 16 ; injection of the bulbs with infective sap on November 16 ; and adding 10 ml. of infective sap to the soil of each pot on January 13. Inoculation of the leaves was the only method that caused infection ; 19 plants out of the 32 showed symptoms, mainly on the inoculated leaves. The varieties differed in their susceptibility to infection and in the severity of the symptoms they showed. The counts for the eight plants of each variety were as follows :

	Severely Affected	Showing Only a Few Necrotic Streaks	Unaffected
Korneforos ..	3	3	2
Alberio	—	7	1
Rose Copland ..	—	4	4
Bartigon	—	2	6

During 1949–50, tests were made on Korneforos, Alberio, Bartigon, White Sail, and Generaal de Wet, using eight plants of each variety for each of four methods of inoculation, and in one of these methods the stipple streak strain of the virus was also tried. This strain causes a systemic necrotic disease of

* In confirming the pathogenicity of these viruses to tulips, de Bruyn Ouboter and Van Slogteren (1949) state that they cause the " Augusta disease ", known in Dutch tulip fields since 1928. The viruses have now also been found severely affecting tulips in the U.S.A. (Fulton, 1950) and in Germany (Uschdraweit, 1952).

French beans in Holland (Bawden and Van der Want, 1949) and it was thought that it might be more invasive than the ordinary strain. The numbers of plants (out of eight) in each variety showing necrotic streaks, chiefly in the outer leaves, as the result of each method of inoculation, were as follows :

Method of Inoculation	Korne-foros	Alberio	Bart-igon	White Sail	Generaal de Wet
Outer scales and tips of bulbs rubbed with inoculum at planting time, Nov. 22	1	—	—	—	—
Infective sap added to the soil, 10 ml. per pot on Nov. 22, Dec. 16 and 31, and Jan. 23 and 26	1	—	—	—	—
Unrolled leaves inoculated when about 2 inches high, when plants brought into glasshouse, Jan. 24.	8	1	—	4	—
As above, but using stipple streak strain of virus, Jan. 24	5	—	—	7	—
Leaves inoculated when 3–5 inches high, Feb. 7	8	5	2	8	1
Untreated controls	—	—	—	—	—

The two strains of the virus behaved similarly, and in the main the only effective method of inoculation was rubbing the virus over the leaves. Korneforos and White Sail were the most susceptible varieties ; the most extensive necrosis occurred in Korneforos.

In both seasons the inoculations failed to reproduce the symptoms of natural infection, and it was thought that infection of the bulb during the previous season might be essential to induce severe systemic necrosis. Nine bulbs of each of the two most susceptible varieties, Korneforos and White Sail, were therefore planted in each of four groups in the open at Rothamsted in January 1950. One of the groups was left untreated as control, and, on the others, three treatments were tried : rubbing the scales of the bulbs with inoculum at planting ; watering the soil round the bulbs three times with a total of 1 litre of infective sap diluted in 9 litres of water, on April 5 and 25, and May 9, 1951 ; and inoculating the leaves on April 5, 1951. The only symptoms seen on the plants during 1951 were some necrotic local spots. The bulbs were lifted on July 10, 1951 and forced in January 1952. Only one plant, of the variety Korneforos, developed the disease, and this was from the group on which leaf inoculation had been done. The symptoms on this plant were very extensive, and were typical of those occurring in naturally infected plants.

OUTBREAKS IN NURSERIES AND TULIP FIELDS

Since 1949, in company with plant pathologists of the N.A.A.S., I have seen 16 outbreaks of the disease in nurseries in the eastern and south-eastern counties of England. The origin of the bulbs could not always be traced, but in eight of the outbreaks the bulbs were newly imported from Holland. The variety Korneforos was affected in seven cases, and Alberio, Krelage's Triump, Crater and Zimmerman each in three. As tobacco necrosis viruses can occur in the roots of seedlings raised in glasshouses (Smith, 1937), these outbreaks

might have been the result of current year infection. The circumstantial evidence suggests, however, that the virus infection occurred during the previous year. In several houses only one of two susceptible varieties grown side by side under the same conditions was affected. In one house, where 6,000 out of 20,000 plants of the variety Zimmerman were affected, all the plants in some boxes were diseased, whereas, in the boxes next to them, every plant was healthy. As all these bulbs were planted in the same lot of soil and treated in the same way, it seemed that only some of the bulbs were infected during the previous year. The grower thought that the healthy and the infected plants came from bulbs taken from different packages in the consignment. In this and other outbreaks there was no correlation between the incidence of the disease and the position of the boxes in the glasshouses, and the temperature of the glasshouse did not seem to influence the appearance of the disease.

On three occasions the disease has been reported in tulips grown as a field crop in England. In one of these, where there were 10 per cent of affected plants in Korneforos and 5 per cent in Scarlet Wonder, the stock had been grown on the farm for three years without any trouble, and the disease appeared when the bulbs were planted in ground that had carried a potato crop in the previous year. As this succession of cropping is by no means uncommon in the bulb-growing areas, it may have been of no significance, but de Bruyn Ouboter and Van Slogteren (1949) have reported that the disease is most prevalent when tulips follow potatoes.

INDICATIONS

The transmission experiments showed that tulip varieties differ in susceptibility, and it is noteworthy that Korneforos, the variety most readily infected artificially, was also the one most often affected in natural outbreaks. The origin of these outbreaks still remains unestablished, but all the evidence suggests that badly diseased plants pick up the viruses, not during the year in which they show the disease, but during the previous year, and that the viruses persist in the bulbs during the dormant stage. That bulb tissues can act as symptomless carriers is shown by the fact that virus can always be recovered from the symptomless main and axillary buds of bulbs, the main shoot of which is necrotic. De Bruyn Ouboter and Van Slogteren (1949) have observed that severely affected tulips almost always die without producing new bulbs, but plants less severely affected can produce apparently normal bulbs. It is, therefore, possible that slight infections, particularly in underground parts, would go undetected, but that the bulbs would give rise to severely infective plants when forced the year after. It was brought to my notice by one grower that small bulbs produced proportionately more diseased plants than did large ones.

Viruses that readily become systemic in plants usually take longer to do so when introduced through the roots rather than through the leaves (Roberts, 1950). Thus it is possible that in forced tulips the time the virus takes to reach the leaves is longer than the growing period of the plant. This may be one reason why, in the transmission tests made in the glasshouse, negative results were obtained with tulips growing in soil watered with infective sap solution.

It is important to know if the low incidence of the disease in tulips grown in the field is a true picture of incidence of infection, or whether many infested plants are unrecognized because their foliage is little damaged. In Holland the disease seems to be more severe in the field (de Bruyn Ouboter and Van Slogteren, 1949), and tobacco necrosis virus also damages runner beans (Bawden and Van

der Want, 1949). There is no evidence to show whether conditions in Holland favour the survival and spread of tobacco necrosis more than here, or whether the viruses in England are more recent introductions.

I am indebted to Mr. W. Buddin, Mr. H. H. Glasscock, Mr. E. C. Large, Mr. J. C. Mather, Mr. J. O. Page, Dr. I. F. Storey and Dr. R. Eric Taylor for bringing outbreaks to my notice and providing much information and material. The bulbs used in the transmission experiments were kindly provided by Dr. E. Van Slogteren of the Laboratorium voor Bloembollenonderzoek, Lisse, Holland.

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NEW OR UNCOMMON PLANT DISEASES AND PESTS IN ENGLAND AND WALES

***Ophiostoma narcissi* on Narcissus Bulbs.** In a sample of rotting narcissus bulbs received from Lincolnshire in October 1953, numerous black and prominently beaked perithecia were found among the inner rotting tissues and also on the dry outer scale leaves. The fungus was isolated, and produced perithecia together with a conidial stage in pure culture on potato-dextrose agar. Both in the bulbs and in culture the fungus agreed with the description of *Ophiostoma narcissi* Limber (*Phytopathology*, 1950, **40**, 493–6). Perithecia of the fungus were found again, later in the same month, on a high proportion of the rotting bulbs in another sample, also from Lincolnshire; but so far they have been found only in bulbs in which the primary rotting could be attributed to some other cause. In most bulbs, Stem and Bulb eelworm (*Ditylenchus dipsaci*) has been present, and it seems probable that the fungus is a saprophyte, or at most only a weak parasite capable of extending the rotting caused by a primary parasite or pest. *O. narcissi* has not previously been noted in this country, but Limber has recorded it in the U.S.A. on bulbs exported from England, Ireland and Holland. J. J. BAKER

Powdery Mildew on Ornamental Pyrethrum. A severe attack of Powdery Mildew was seen on some experimental plots of ornamental pyrethrum (*Chrysanthemum coccineum*) at Luddington, Warwickshire, in August 1953. The varieties most severely affected were E. M. Robinson, Queen Mary and James Kelway. Cleistocarps typical of *Erysiphe* spp. were present on some of the leaves; they contained 4–6 asci, in each of which there were 2 or, occasionally, 3 ascospores measuring 26–33 × 13–20μ. The identity of this fungus is difficult to determine; it is obviously near to *E. cichoracearum* DC. and it may be *E. polyphaga* Hammarlund, although the spores are larger than those recorded for this fungus on other hosts. There does not appear to be any previous record of *Erysiphe* spp. on *Chrysanthemum coccineum*. Three species have been reported on other *Chrysanthemum* spp. *Erysiphe communis* was listed by Jaczewski (*Karmanni opridielitel gribov.* 2. *Lief. Mehltaupilze.* Leningrad, 1927) on *Chrysanthemum parthenium*. *Erysiphe cichoracearum* has been found on *Chrysanthemum corymbosum* (*Bull. Soc. vaud. Sci. nat.*, 1951, **65**, 41–7), and Blumer (*in lit.*) confirms that our fungus is different. *Oidium chrysanthemi* claimed by Hammarlund, (*Bot. Notiser*, 1945, 101–8) to be the imperfect stage of *Erysiphe polyphaga*, is common here and abroad on a number of *Chrysanthemum* spp.; the perfect stage has been recorded only on a few of the many other hosts that this fungus attacks.

R. ERIC TAYLOR AND F. JOAN MOORE

Stem Rot of Violet. In May 1953 some cultivated violets in a garden at Burwarton, Shropshire, were found to be affected with a stem rot. Sporodochia of *Myrothecium roridum* Fr. were present on the rotting tissues. Although this fungus is well known as the cause of Stem Rot of viola and pansy, this is the first record of its occurrence on violet (*Viola odorata*) in Britain. N. C. PRESTON

Root Eelworm on a Cactus. In March 1953, a plant of *Coryphantha* sp., whose roots were infested with cysts of a *Heterodera* species, was sent to the Plant Pathology Laboratory at Harpenden. The plant, which showed no obvious signs of damage by the eelworm, was from a consignment of assorted cacti imported from Spain. The cysts on the roots were dormant ones and had presumably been formed during the previous growing season. After removing a few cysts for examination, the plant was repotted in a sterile sandy compost. Towards the end of July, the plant was removed from the pot and the roots carefully washed. Several freshly-formed females or cysts of *Heterodera* were found attached to the roots; two of these were golden-brown in colour but the rest were still white. The plant was repotted and examined again one month later, and by this time nearly all the new cysts had turned brown.

As a result of examining the old cysts and their contents and, later, freshly-formed white and brown cysts, the following features were noted: the cysts were small and lemon-shaped; the larvae were about the same size as those of *Heterodera schachtii*, the beet eelworm; the cysts showed no egg-sac and no sign of a subcrystalline layer, except for a very slight chalky deposit on the surface of some of the white females. From these characters the eelworm was identified as *Heterodera cacti* Filipjev and Schuurmans Stekhoven 1941. No males were found. Its occurrence on *Coryphantha* sp. is a new host record for this nematode; the only previous published record was on two species of cactus in Holland in 1932 (Franklin, M. T. *The Cyst Forming Species of Heterodera*, 1951).

J. F. SOUTHEY

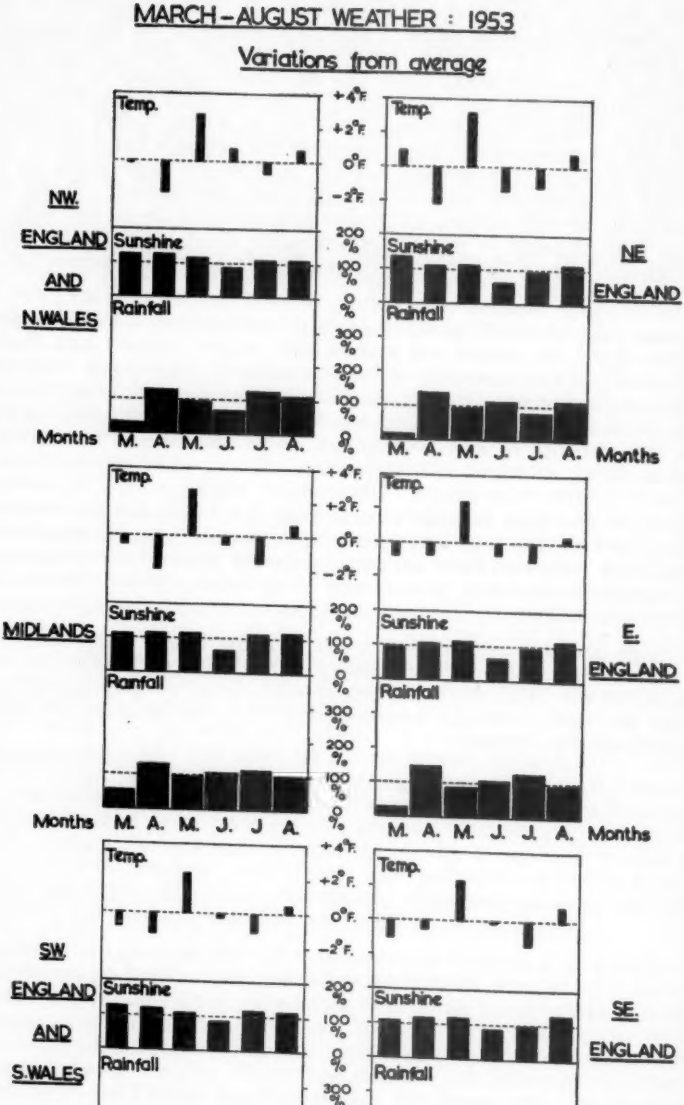
SWEDE MIDGE IN ENGLAND AND WALES, 1953

In many parts of England and Wales abnormally heavy attacks of the Swede midge (*Contarinia nasturtii* (Kieff.)) were experienced in the late summer and early autumn of 1953. Reports received in July and subsequently indicated that damage to many brassica crops was very heavy, especially in Northumberland and Durham, where in some districts 80 per cent of the plants were attacked. In Yorkshire and Lancashire damage was not so severe, and in the Midlands and eastern counties damage was widespread but not on a heavy scale. In the south-east, however, the damage was the most severe experienced for many years and a considerable range of brassica crops was attacked. In the south-west up to 75 per cent of some crops were damaged, and severe and widespread damage also occurred in mid-Wales, especially Cardiganshire. In southern Wales attacks were only light and confined to early crops ; later-sown crops were practically free.

Swedes suffered most, but damage also occurred on broccoli, cabbage, kale and rape. On swedes and turnips the " many-necked " and " crumple leaf " condition was common, whereas on other brassica crops " blindness " was the chief symptom. Damage, particularly to swedes, was often followed by attacks of bacterial soft rot, causing secondary rotting of the crowns. In Devon, where two varieties of kale were grown in the same field, the marrowstem kale was heavily attacked, with subsequent soft rot, while thousandhead kale was relatively free from injury. Observations made on plots of varieties of fodder rapes and kales in mid-Wales showed that heavy damage occurred on rape kale and Hungry Gap kale ; all types of marrowstem, thousandhead and canson kales were free from damage. Adjacent plots of the resistant types were completely unmarked, even on sites where the susceptible varieties showed a 100 per cent attack.

The high incidence of damage to crops by midge was probably more noticeable than usual because of the frequency with which attacks were followed by bacterial soft rot. This rot, in its turn, appeared to do more damage than usual because the wet conditions experienced in the late summer favoured the development of the disease.

Plant Pest Survey


MARCH – AUGUST WEATHER : 1953
Variations from average
NW. ENGLAND AND N.WALES
NE. ENGLAND
MIDLANDS
E. ENGLAND
SW. ENGLAND AND S.WALES
SE. ENGLAND
Temp.
Sunshine
Rainfall
+4°F.
+2°F.
0°F.
−2°F.
200 %
100 %
0 %
300 %
200 %
100 %
0 %
Months
M. A. M. J. J. A.

THE WEATHER OF ENGLAND AND WALES*

SPRING AND SUMMER, 1953

Little or no rain fell over most of the country during the first 25 days of March ; the only previous March on record with less rain in England and Wales was 1944. Sunshine totals were high but, except in north-east England, the mean temperature was below average. Low night minimum temperatures and fogs were frequent during the drought. A fine spell occurred in April from the 18th to the 25th, but the rest of the month was cool and unsettled with considerable rain ; sunshine totals were again high. May was warm, being the only month of the spring and summer with temperatures above average in all areas ; a few late spring frosts were recorded. The warmest days of the month occurred on 24th and 25th, temperatures nearing 90° F. being reached in the London area. May sunshine was above average.

June was a dull humid month, especially in east and north-east England and the Midlands. The first three weeks were cool, but it became warmer after the 22nd. The rainfall was below average in many areas, although heavy local thunderstorms gave rise to large totals in some places in eastern England and the Midlands. July was unsettled and mainly wet, especially in the south ; heavy thundery rain again occurred locally, and general temperatures were below average. Settled fair weather prevailed for the first half of August, but changeable weather returned later and rain became frequent. Temperatures over 90° F. were reached on the 12th.

The weather in each of the six months, March to August (inclusive), is represented graphically on page 32. Figures for six districts of England and Wales are shown in terms of deviation from average for air temperature, and in terms of percentage of average for sunshine and rainfall. Apart from the dry March, the regular rainfall throughout the period is clearly illustrated in the diagrams. Despite the rain, sunshine totals were high, except in June. The warm weather in early August was counterbalanced by a subsequent cool spell, so that in these monthly representations, August does not show as an abnormally warm month.

YELLOW RUST OF WHEAT IN ENGLAND AND WALES, 1953

In contrast to 1952 (*Plant Pathology*, 1953, **2**, 37–8), Yellow Rust, *Puccinia glumarum* (Schm.) Erikss. & Henn., appeared late in 1953 and, with one or two exceptions, never became serious. There were a few early records. It was first seen in mid-March on a plot of September-sown Jubilégem at Cambridge, and during May a few reports of very slight infection were received from Worcestershire, Norfolk and Essex. In June slight infection was reported in a few crops in the north, Midlands and south-west, but only one severe attack, on Pilot in Northumberland, was noted. In most parts of the country the disease did not appear until July, and even at the end of the month it was

* These notes, and the diagram on page 32, are provided by the Agricultural Branch of the Meteorological Office, and published by permission of the Director.

nowhere prevalent and usually only slight. A few severe attacks were seen on Nord Desprez in the eastern and south-eastern counties. The incidence of the disease on a farm in Berkshire is worth special mention. There were a number of crops of Nord Desprez on this farm and at the end of June 20–50 per cent infection was recorded on some of them and only about 1 per cent on others. Cultural treatments had been similar on all fields and it seemed that these striking differences were probably associated with the type of soil; all the severely-affected crops were on alkaline soils, whereas the others were all on Gault loam.

Dr. C. C. V. Batts of the National Institute of Agricultural Botany again carried out a survey of the physiologic races of Yellow Rust, and he has kindly provided the following information. In general, the distribution of the races was similar to that recorded in previous years. Race 8 was present in all parts of the country and was collected on the varieties Alpha, Demeter, Jubilégem, Pilot, Squarehead II, Squarehead's Master and Yeoman. In the southern counties and parts of the Midlands, race 2 and biotype 2B were present. Race 2 occurred on Eclipse, Holdfast and Nord Desprez. Biotype 2B, which was first identified in 1952, was found this year as far north as Lincolnshire and Worcestershire. Inoculation tests have indicated that this biotype is a more virulent form of race 2 and will attack Cappelle Desprez, which is resistant to race 2; it has been found on Cappelle Desprez, Nord Desprez and Eclipse.

Last year, when Yellow Rust was prevalent and often severe, spring temperatures were high; this year the early spring temperatures were low (see the weather chart on p. 32). The cold conditions during the autumn of 1952 were probably unfavourable for early infection in autumn-sown crops.

Plant Disease Survey

JAPANESE BEETLE FOUND IN AIRCRAFT AT PRESTWICK, AYRSHIRE

Since the Japanese beetle, *Popillia japonica* Newman, was accidentally introduced in nursery stock into New Jersey about forty years ago, it has spread rapidly in all directions and now infests about 40,000 square miles of the eastern United States of America. In its native country (Japan) it is not regarded as a serious pest, but in America it has proved to be a pest of major importance and exceedingly difficult to control. As an adult beetle, it is an omnivorous and voracious feeder on the foliage of many fruit and shade trees and ornamental plants; as a grub, it attacks the roots of grasses and often causes severe injury to grassland, turf and lawns. A community effort is necessary for effective control. The finding of a live beetle in the luggage compartment of an American military airliner at Prestwick last August—and the report that three live beetles, thought by local officials to be of the same species, had previously been found in similar circumstances in 1952 and 1953—has emphasized the danger of its introduction into European countries and the need for vigilance at airports, particularly during the summer and autumn months.

W. P. L. CAMERON

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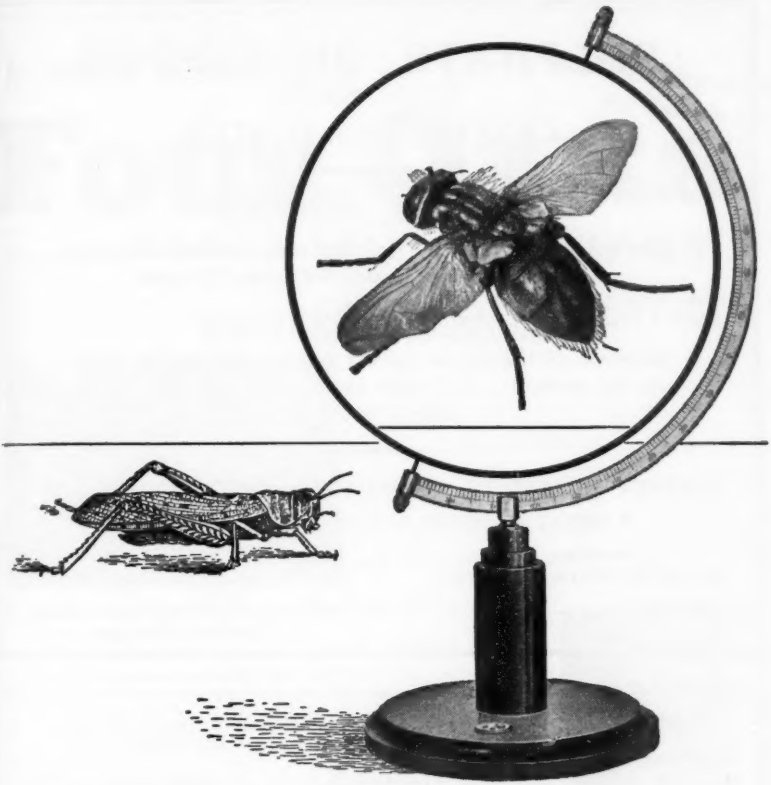

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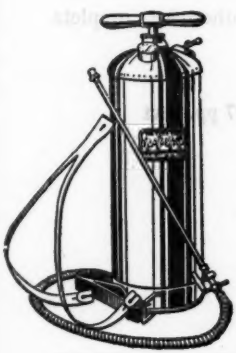

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